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ENGINEERING PROPERTIES OF PADDY FOR DESIGNING OF THRESHING MECHANISM

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ABSTRACT

Harvesting, threshing and winnowing are the final operations which play the significant role in realizing the full benefit of raised crop. The morphological characteristics of paddy plant are essential to know for operating settings of the harvesting machineries. The single grain detachment and stripping force are important parameters for design and development of different mechanism for threshing. The morphological characteristics of paddy plant, physical properties of paddy grain, single grain detachment force, panicle stripping force, bulk density and paddy uprooting force were studied following the standard procedures. The Ratnagiri-1 is popular variety of Konkan selected for this study. The morphological characteristics of paddy plant like plant height, plant dropping height, panicle height, panicle length and stem diameter were found to be 851.7, 744.6, 648.1, 203.6, and 1.77 mm respectively with number of tillers per hill to be 9.07. Thousand grain weights were found to be in the range from 29.27 to 27.77 g and 31.11 to 29.37 g at 19.90 and 22.05 % moisture content (wb) respectively. The maximum single grain detachment force was found to be 3.07 N at 19.47 per cent moisture content (wb). The maximum stripping force for paddy panicle was found to be 20.59 N at 22 to 26 per cent moisture content of (wb). The single grain detachment and stripping force for paddy panicle found to be decreased in magnitude with decrease in moisture content. The minimum paddy uprooting force was found to be 19.4 kg at 35.09 per cent moisture content of soil, where as maximum uprooting force for paddy was found to be 40.2 kg at 17.5 per cent moisture content of soil.

KEYWORDS: Stripping, Paddy, Engineering Properties, Grain Detachment Force, Stripping Force & Uprooting Force

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Original Article

INTRODUCTION

Rice is an important crop on which food security of the world is strongly associated as it is the staple food of half of the world's population [1]. China and India are the two biggest rice producers in the world with production of 141.4 million tonnes and 106.54 million tonnes of paddy respectively, i.e. almost 50 % of the world rice production [2]. Maharashtra is one of the major producer of rice about 2.83 million tones with the productivity of 1880 kg/ha during the year 2014-15 [3]. Konkan, is a major producer of rice, cultivated over an area of 3.86 lakh hectares with an annual production of about 10.84 lakh tones and average productivity of 2810 kg/ha [3].

The act of harvesting can be picking, pulling, plucking, slashing, cutting, stripping and shaking the economic part of the plant that is of interest to the harvester [4]. In Konkan, paddy harvesting and threshing is done manually with a sickle, which is very drudgerious and time-consuming operation is generally done by women labour. Konkan is a major tribal area of Sahyadri and having small and fragmented land, so women constitute the real workforce in the cultivation of rice. Studies have shown that the male migration to urban areas and diversion of the work force to non-farm sectors would bring women to center stage of all household activities in which rice farming is the most important one [5]. Mechanized harvesting is done with the help of reaper and reaper binder which saves time and money compared to manual harvesting [6][7]. The fast and efficient method of harvesting is the immediate need of the farmers for time-saving during the peak season of harvesting. At such stage, when timeliness of harvesting and threshing operations is the main criterion, the use of combine harvesters for the harvesting of the crop should be the most appropriate.

Harvesting and threshing operations may be done separately or in "one go" depending upon the availability of labours and equipment. Nowadays, combine harvesters are becoming popular among the farmers as it performs cutting, threshing and winnowing operations simultaneously thus saving the time as well as reducing drudgery. The stripper combine harvester are popular in western countries having the main advantages of the stripper harvester are the possibility of increasing the harvesting capacity at a reduced power requirement and more combining hours at harvest. Most of the straw is left un-harvested in the field. The reduced straw intake also offers potential for a reduction in size and weight for a machine of given capacity [8].

Agricultural operations can be made comfortable and efficient by designing the machineries which are having good performance and power efficient. Engineering properties of paddy grains are required for designing of machineries like thresher, cleaner, grader, separator etc. Morphological characteristics of paddy plant were essential for operating settings of the harvesting machineries and stripper combine harvesters. The density and volume of grains are the important parameters for designing of storage tank at a required capacity. Hence the moisture dependent properties of the paddy grains are essential for design and development of agricultural machineries.

The power requirement of the different threshing mechanism is depend upon the moisture content of grains. The capacity and performance index of combine harvester and stripper combine harvester operating parameters were depends on morphological characteristics of paddy plant. The objective of this study was to investigate the some engineering properties of paddy (Ratnagiri-1) in relation to design parameters of threshing mechanism.

MATERIALS AND METHODS

Morphological Characteristics of Paddy Plant

Morphological characteristics of the paddy plant were measured at the physiological maturity of the crop. The characteristics like plant height, panicle height, plant dropping height, panicle length, stem diameter and number of tillers per hill were measured. The morphological characteristics of paddy plant were measured using 100 cm scale and particularly stem diameter was measured using digital vernier caliper (L.C. 0.01 mm) shown in Figure 1. The moisture contents of grain and material other than grain (MOG) was measured using oven method. The terminologies are explained as below and also illustrated in Figure 1.

Plant height (Yc): The length of the plant from its base at ground level to its upper tip when the plant is straightened.

Plant Dropping Height: The length of the plant from its base at ground level to its upper tip when the plant is not straightened.

Panicle Height (Ys): The length of the plant from its base at ground level to the base of panicle.

Panicle Length (l): The length of the panicle from its base to the top of panicle in straightened position.

Stem Diameter (D): It is measured at the top internode at which panicle initiates with the help of vernier caliper.

Number of Tillers: The number of plants/tillers per hill.

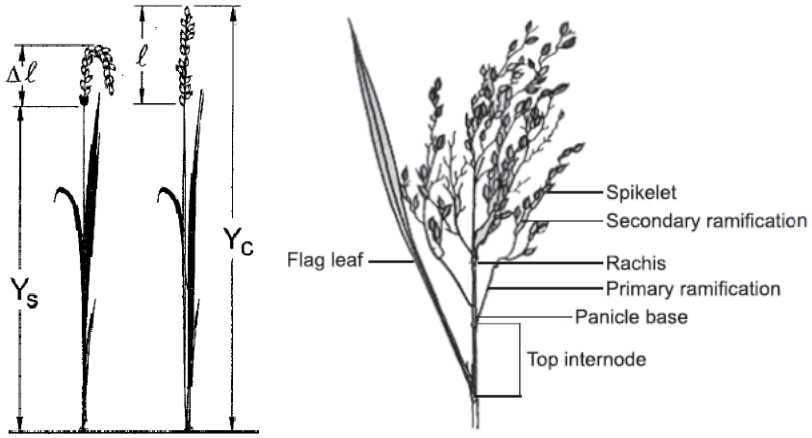

Figure 1: Measurement of Physical Properties of Paddy Plant [9][10]

Physical Properties of Paddy Grain

Sample Preparation

The paddy grains (*Cv.* Ratnagiri-1) were cleaned using hand operated winnower to remove foreign matter such as dust, straw and un-filled grains. The initial moisture content of the paddy grains was measured using oven method. The physical dimensions for twenty randomly selected paddy grains viz. length (L), breadth (B) and thickness (T) were measured using vernier caliper (L.C. 0.01 mm). Geometric mean diameter and sphericity were calculated with formulae.

Geometric Mean Diameter (D_e)

The geometric mean diameter (D_e) considering a prolate spheroid shape for a paddy grain was determined using expression as described under [11]

$$D_e = \sqrt{\text{length(L)} \times \text{breadth(B)} \times \text{thicness(T)}} \quad (1)$$

Where,

L = largest intercept;

B = largest intercept perpendicular to L;

T = largest intercept perpendicular to L and B.

Spericity (Ø)

The sphericity (Ø) is defined as the ratio of the surface area of the sphere having the same volume as that of grain

to the surface area of the grain was determined using expression as described [11].

$$Ø = \frac{\text{Geometric mean diameter } (D_e)}{\text{Length}(L)} \quad (2)$$

Thousand grain weight (TWG)

The thousand grain weight was determined by randomly selecting one thousand grains from the paddy sample and weighed. Ten samples were taken at three moisture content [12].

Bulk Density

Bulk density is the ratio of mass of rice grains (*M*) to its total (bulk) volume (*V*). It was determined by filling a known volume of container with rice grains and gently tapped without compact the grains during filling (Figure 2). The cylindrical shaped container was used and its volume was computed using formula based on diameter and height. The weight of the grain in the container was measured separately. The bulk density was calculated using following formula. Total ten samples of paddy grain (cv. Ratnagiri-1) were taken and bulk density was determined. The same method was given by Singh and Singh (2010) for paddy grain.

$$\text{Bulk Density } (kg/m^3) = \frac{\text{Weight of sample, kg}}{\text{Volume occupied by the sample, } m^3} \quad (3.3)$$

Figure 2: Bulk Density Measurement Setup for Paddy Grain

Grain Detachment Force

Grain detachment force was determined by using Universal Testing Machine (Make: Shimazdu, Capacity- 50 KN and L.C. – 0.1N). The force required for detaching a single grain from the panicle and stripping force required to strip paddy panicle were determined as described below.

Single Grain Detachment Force

Single grain detachment force is the force required to detach a single grain from the primary branch of the panicle. For measuring single grain detachment force two wooden jaws of a hard wooden block (45×25×22 mm) having 2 mm slot at the centre was used for holding the grain and secondary ramification respectively with nut and bolt. One wooden jaw was mounted on the upper jaw and other on the lower jaw. Grain was clamped in the upper wood jaw while the secondary ramification of grain was clamped in the other jaw. For testing, a loading rate of 1 N/s was applied with the crosshead speed of 1 mm/min. The maximum force required for grain detachment was recorded. This procedure was followed for

four different moisture levels with three replication for randomly selected paddy panicles.

Paddy Panicle Stripping Force

The paddy panicles were randomly selected from the paddy field for the stripping force measurement. The specially fabricated paddy grain stripper made from 3 mm bakelite sheet (having 4 mm ϕ hole) was fixed in the upper jaw using 12 mm M.S. square rod as shown in Figure 3. For determining the stripping force, the wooden blocks (45×25×22 mm) as mentioned above was used for holding the top internode of the panicle (Figure 4). This block was fixed in the lower jaw of UTM. Top internode of panicle was firmly clammed in the block tightening using nut and bolts. Care was taken that the panicle stem should not be cut during the holding the panicle in the jaw and the panicle should remain in tangential in both jaws. For testing, loading rate of 1 N/s was applied through the cross head speed of 1 mm/s. The maximum force required for stripping a paddy panicle was recorded. This procedure was replicated for 5 times for three different moisture levels of randomly selected paddy panicles.

Figure 3: A Specially Fabricated Paddy Stripper for Stripping Force Measurement

Figure 4: Measurement of Stripping Force of Paddy Using UTM, Special Jaw and Stripper

Paddy Uprooting Force

The force required to uproot one hill of paddy was measured using load cell (Figure 5). The load cell (0-125 kg with 0.1 kg least count) was tied between the tie rod end to paddy hill base. The uprooting force was determined to apply the pull force through rod ends. The maximum force reading on the digital indicator was recorded. Five observations were taken for different soil and straw moisture content.

Moisture Content of Material Other Than Grains (MOG) and Grains

The moisture content of each sample was determined on wet basis using the AOAC standard method [13] and calculated as given below.

$$MC_{wb} = \frac{W_{initial} - W_{final}}{W_{initial}} \times 100 \quad (4)$$

Where,

MC_{wb}= Moisture content on wet basis, %;

$W_{initial}$= Initial weight of the sample, g;

W_{final}= Final weight of the sample, g.

Figure 5: A Tie Rod and Load Cell Arrangement for Paddy Uprooting

RESULTS AND DISCUSSIONS

Morphological Characteristics of Paddy Plant

The morphological characteristics of paddy plant viz. plant height, plant dropping height, panicle height, panicle length, the number of tillers and stem diameter were measured. These properties of the plant were measured at the physiological maturity of the crop. The mean value of 40 individual observations of morphological characteristics of the paddy plant is shown in Table 1. The mean values of morphological characteristics of the paddy (Cv-Ratnagiri-1) plant viz. plant height, plant dropping height, panicle height, panicle length and stem diameter was found to be 851.7, 744.6, 648.1, 203.6, and 1.77 mm respectively with a number of tillers per hill to be 9.07.

The plant height and plant dropping height of the plant were main morphological characteristics related to the machine operational parameters. The combine harvester material other than grain handling can be reduced by adjusting the cutter bar height from the ground, which reduced the feed rate to the threshing cylinder reducing the cylinder losses and increasing the threshing efficiency. Based on these characters stripping rotor height and hood height of stripper combine harvester were made adjustable. The stem diameter and number of tillers were used for deciding the key hole diameter of the stripping element.

Table 1: Abstract of Morphological Characteristics of Paddy Plant

Particulars	Plant he$ight, mm	Dropping Height, mm	Panicle Height, mm	Panicle Length, mm	Number of Tillers	Stem diameter, mm
Mean	851.7	746.4	648.1	203.6	9.07	1.77
Max.	1016	885	787	241	20	2.1
Min.	690	590	530	150	5	1.5
Std. Dev.	7.60	7.16	5.96	2.67	2.97	0.19

Physical Properties of the Paddy Grain

The physical properties of the paddy grains viz. length, breadth, thickness and thousand grain weight (TGW) were measured at two moisture content and geometric mean diameter (D_e) and sphericity (Ø) was calculated. The mean values of 20 individual observations of paddy grains are presented in Table 2. It is observed that TGW ranges from 29.27 to 27.77 g and 31.11 to 29.37 g at 19.90 and 22.05 % moisture content of grain respectively. The result showed that as the moisture content of grain increases the mean values of the physical properties of paddy grain increases. The similar type of trend was found to Pandiselvam [14]. The moisture dependent properties of paddy grains can be used for designing of grain storage bin.

Table 2: Physical Properties of Paddy Grains (Cv. – Ratnagiri-1)

Grain M. C., %	Particulars	Length, mm	Breadth, mm	Thickness, mm	GMD, (De)	Sphericity, (Ø)	TGW, g
19.90	**Mean**	9.26	3.22	2.09	3.90	0.42	28.49
	Max.	9.81	3.63	2.22	4.08	0.44	29.27
	Min.	8.87	2.76	1.99	3.77	0.38	27.77
	Std Dev.	0.313	0.232	0.069	0.101	0.017	0.578
22.05	**Mean**	9.68	3.21	2.24	4.05	0.42	30.43
	Max.	10.21	3.41	2.35	4.28	0.44	31.11
	Min.	9.12	2.93	1.96	3.89	0.4	29.37
	Std Dev.	0.372	0.159	0.117	0.119	0.012	0.631

Bulk Density

Bulk density of paddy grain was measured at moisture content of 13.35 per cent. The bulk density of paddy was found in the range of 559 to 573 kg/m^3 with mean of 568 kg/m^3. The bulk density of paddy grain was considered for deciding the capacity of grain tank.

Single Grain Detachment Force

Single grain detachment force was measured for three samples at four moisture contents levels. The mean detachment force of single grain at a different moisture content of grain is shown in Table 3. Grain detachment force was found to be decreased from 3.09 to 2.23 N with a decrease in moisture content from 19.47 to 15.21 %. It was observed that force required to detaching a single grain decreased in magnitude with a decrease in moisture content of grain. The decrease in detachment force with a decrease in moisture content of grain might be due to decrease in binding of grain with pedicel. The similar type of result was observed by Szot [15] and Kawamura [16]. The force requirement is used for designing the threshing cylinder and calculating power requirement of power different capacity.

Table 3: Detachment Force of Single Grain

Sr. No.	Grain Moisture Content, %	Mean Single Grain Detachment Force, N
1	19.47	3.09
2	18.61	2.91
3	16.85	2.53
4	15.21	2.23

Paddy Panicle Stripping Force

Maximum stripping force required to strip paddy panicle (5 samples) was measured at three moisture levels of

grain and five samples. The maximum stripping force (mean value) for stripping panicle is shown in Table 4. Mean maximum stripping force was found to be 20.59N at 22-26 per cent moisture content of grain. It was found to be maximum at higher moisture content and minimum at lower moisture level. It was observed that, stripping force was decreased in magnitude with a decrease in moisture content of grain. The similar type of trend was observed by Kawamura [17]. The panicle stripping force was required for calculating for requirement of stripper rotor of stripper combine harvester. The depending upon the length of stripper rotor the small and light weight machineries can developed for the small and fragmented land holding of India.

Table 4: Stripping Force Requirement for Paddy Panicle

Sr. No.	Grain Moisture Content, %	Maximum Stripping Force, N
1	22-26	20.59
2	18-22	18.01
3	14-18	13.54

Paddy Uprooting Force

The paddy uprooting force requirement was determined at three moisture levels of the paddy plants and five moisture levels of soil. At physiological maturity of the crop, the uprooting force was measured at different places in the field. The mean paddy uprooting force for different moisture content of soil and straw is shown in Table 5. The minimum paddy uprooting force was observed to be 19.4 kg at 35.04 and 77.38 per cent moisture content of soil and paddy straw respectively. The maximum paddy uprooting force was observed to be 40.2 kg at 17.5 and 73.47 per cent moisture content of soil and straw respectively. It is observed that paddy uprooting force was increased with the decrease in moisture content of soil. The changes in paddy uprooting force with decrease in moisture content soil might be due to hardening of soil and roots strongly attached to soil. The similar type of result was observed for vetiver grass with uprooting for in the range of 19.36 to 70.33 kg Mickouski, [18].The uprooting force was determined to confirm that the stripping force is less than the uprooting force. The uprooting force determination confirmed that the stripping force action during the machine operation it will not uproot the plants.

Table 6: Uprooting Force at Different Soil and Straw Moisture Content

Sr. No.	Moisture Content of Soil, %	Moisture Content of Straw , %	Mean uprooting Force, kg
1	35.09	77.38	19.4
2	28.85	77.38	21.2
3	21.23	74.69	23
4	19.13	74.69	32.8
5	17.5	73.47	40.2

CONCLUSIONS

Grain detachment force and panicle stripping force are the most important parameters on which power requirement of threshing mechanism depends. The information of these forces is essential for the design of different threshing mechanism. Force requirement for grain detachment and stripping decreased in magnitude with a decrease in moisture content of grain. The uprooting force of paddy also depends on moisture content of soil. The morphological characteristics of paddy plants are essential to know for deciding range of operating settings of the combine harvester as well as stripper combine harvester like stripper rotor and hood height, so that it can be made adjustable in field. The mean values of morphological characteristics of the paddy (*Cv*-Ratnagiri-1) plant viz. plant height, plant dropping height, panicle

height, panicle length and stem diameter was found to be 851.7, 744.6, 648.1, 203.6, and 1.77 mm respectively with number of tillers per hill to be 9.07. Thousand grain weights were found to be in the range of 29.27 to 27.77 g and 31.11 to 29.37 g at 19.90 and 22.05 % moisture content of grain (wb) respectively. The bulk density of paddy was found in the range of 559 to 573 kg/m^3 with mean of 568 kg/m^3. The maximum single grain detachment force was found to be 3.09 N at 19.47 per cent moisture content of grain (wb). The maximum stripping force was found to be 20.59 N at 22-26 per cent moisture content of grain (wb). The minimum paddy uprooting force of 19.4 kg was found to be 35.09 per cent at moisture content of soil.

REFERENCES

1. *Aslam, M.M., M., Zeeshan, A. Irum, M.U. Hassan, S. Ali, R. Hussain, P.M.A. Ramzani, and M.F. Rashid. (2015). Influence of seedling age and nitrogen rates on productivity of Rice (Oryza sativa L.): A Review. American Journal of Plant Sciences, **6**: 1361-1369.*
2. *Anonymous. 2015a. Rice market monitor, FAO, 18(1).*
3. *Anonymous. 2016. www.Mahaagri.gov.in. Department of Agriculture, Government of Maharashtra.*
4. *Anonymous. 2015b. Handbook on rice post harvest techniques, Under Department of Agriculture and Livestock (NDAL) and Japan International Cooperation Agency (JICA), project on promotion of smallholder rice production (phase2).*
5. *Anonyoums. 2013b. Vision 2050, Central Rice Research Institute, Cuttack, ICAR.*
6. *Manjunatha, M.V., B.G. Masthana Reddy, S.D. Shashidhar and V.R. Joshi. 2009. Field performance evaluation of vertical conveyor paddy reaper. Karnataka Journal of Agricultural Sciences, 22(1): 140-142.*
7. *Prakash, R. Jaya, B. A. Kumar, Reddy, G. A. and K.V.S. Rami. 2015. Performance evaluation of reaper-binder in rice crop. Internat. J. Agric. Engg., 8(2): 232-238.*
8. *Tado, C. J. M., P. Wacker, H.D. Kutzbach, and D.C. Suministrado, 1998. Development of stripper harvesters: A Review. J. Agric. Engg. Res. 71: 103-112*
9. *Tado, C. J. M. 2002. Influence on the performance of the stripper rotor in rice. Published Ph. D Distertation, Institute of Agricultural Engineering, University of Hohenheim, Germany.*
10. *Wopereis, M.C.S., T. Defoer, P. Idinoba, S. Diack and M.J. Dugué, 2008. Participatory Learning and Action Research (PLAR) for Integrated Rice Management (IRM) in Inland Valleys of Sub-Saharan Africa: Technical Manual. WARDA Training Series. Cotonou, Benin: Africa Rice Center: 26-33.*
11. *Mohsenin, N.N. 1986. Physical properties of plant and animal materials. Second and updated edition, Gordon and Breach Science Publishers Icn.*
12. *Varnamkhasti, M.G., H. Mobli, A. Jafari, A.R. Keyhani, S. M. Heidari, S. Rafiee, and K. Kheiralipour. 2008. Some physical properties of rough rice (Oryza Sativa) grain. J Cereal Sci, 47, pp. 496-501.*
13. *Helrich, K. 1990. AOAC: Official Methods of Analysis 1, 15th Edition.*
14. *Pandiselvam, R., V. Thirupati, and S. Mohan. 2015. Engineering properties of rice. Agricultural Engineering. 3:69-78.*
15. *Szot, B. A., C. J. M. Tado, P. Wacker, H.D. Kutzbach, and D.C. Suministrado, 1998. Development of stripper harvesters: A Review. J. Agric. Engng Res. 71: 103-112*
16. *Kawamura, T., Koichi Shoji, and Masaru Tokuda. 2002. "Measurement of force detaching single grain of rice." Journal of the Japanese Society of Agricultural Machinery, 64 (5):116-122.*

17. *Kawamura, N., H. Horio and Y. Sasaki. 1968. Mechanical properties of rice ear and grain. Journal of the Japanese Society of Agricultural Machinery. 30(2): 88-92,105.*

18. *Mickouski, S.B., L.P.H. Van Beek and F. Salin. 2005. Uprooting of vertiver uprooting resistance of vertiver grass. Plant and Soil. 278:33-41.*